AD-A138 330 THE EFFECT OF HAZE ON AN OPERATOR'S VISUAL FIELD AND HIS TARGET DETECTION PERFORMANCE(U) SYSTEMS RESEARCH LABS INC DAYTON OH W N KAMA ET AL. NOV 83 1/1

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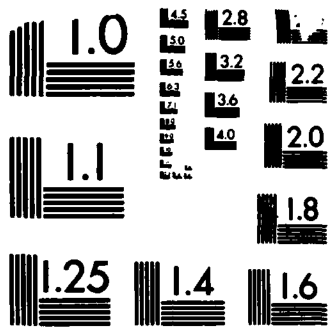
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AFAMRL-TR-83-066

THE EFFECT OF HAZE ON AN OPERATOR'S VISUAL FIELD AND HIS TARGET DETECTION PERFORMANCE

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NOVEMBER 1983

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FOR THE COMMANDER

CHARLES BATES, JR.
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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: AFAMRL-TR-83-066	2. GOVT ACCESSION NO.: A138330
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): THE EFFECT OF HAZE ON AN OPERATOR'S VISUAL FIELD AND HIS TARGET DETECTION PERFORMANCE.	5. TYPE OF REPORT & PERIOD COVERED: Technical
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): William N. Kama, *Martha D. Hausmann, Louis V. Genco, OD, Lt Col, USAF, *Mary Ann H. Barbato	8. CONTRACT OR GRANT NUMBER(s): F33615-82-C-0511
9. PERFORMING ORGANIZATION NAME AND ADDRESS: AFAMRL, Human Engineering Division, AMD, AFSC, Wright-Patterson AFB OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62202F, 7184-18-03
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: November 1983
	13. NUMBER OF PAGES: 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*Systems Research Laboratories, Inc., 2800 Indian Ripple Rd., Dayton, OH 45440

AFAMRL Primary Investigator: Mr. W.N. Kama, AFAMRL/HEF, Tele: 513 255-3325

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Windscreen
Visual Field
Aircraft Transparencies
Haze
Target Detection
Visual Performance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study was conducted to determine what type of relationship, if any, exists between the amount of haze emanating from a transparency and the percent of an operator's visual field that is "lost". The effect of this haze on his ability to perform a target detection task was also determined. Ten subjects performed a simple target detection task in which they were required to indicate when they could see a slowly moving, 1.0 minute of arc, 80% contrast target that traveled in 8 (0, 45, 90, 135, 180, 225, 270 or 314 degrees) different angular directions from the center of a background screen towards the

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periphery. The subjects performed this task while looking through haze test panels mounted at 90°, 63° or 45° to their line of sight and which when illuminated by a bright light source mounted at the center of the background screen resulted in haze conditions of 2%-3.5%, 5%-10%, 15%-26% or 25%-48%. A baseline condition in which no test panel was interposed between the subject, the task, and the bright light source was also administered. Subject performance was evaluated in terms of (1) the distance the target had moved before being seen, and (2) the number of times that it was not detected. The results of this study indicated that as the percent of haze present in a transparency increased, the percent of an operator's background FOV that is occluded also increased but that the percent of targets detected decreased. It is suggested that htese two relationships can be used as an objective yardstick for arriving at decisions as to when a transparency should be replaced due to the amount of haze present in it.

PREFACE

This report was prepared by the Crew Systems Effectiveness Branch of the Human Engineering Division, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH. The work was performed under Task 718418, "Visual Effects of Windscreens on Pilot Performance," Work Unit 71841802, "Optical Properties of Windscreens." The authors wish to express their sincere thanks and appreciation to Ms Mary Ann Howes and Becky Unger who contributed much time and effort to the successful completion of this study. Funding for this project was provided by the Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory, Vehicle Equipment ADP Branch (AFWAL/FIEA).

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INTRODUCTION

As a transparency ages, and as it is repeatedly cleaned, many small scratches appear on its surface. These scratches act as light scatterers and cause the canopy or windscreen to "light up" under some conditions, especially when an aircraft is flying directly into the sun (or some other bright light source). This "lighting up" or halation condition has its prime effect on the visual system by reducing the contrast of an object or target. This reduction in contrast not only makes it impossible to detect or locate small targets but may make even large targets, such as runways, disappear.

Since haze is a time-dependent problem, becoming significantly worse with the age of the transparency, the question arises as to when such transparencies should be replaced. Current practice is to leave this decision to the pilots, the offending transparency being replaced when enough complaints have been directed against it. Although this is a reasonable means for arriving at such a decsion, this process is a highly judgmental one and not very cost effective should such transparencies be replaced before they really needed to be.

What is required therefore, is a method or technique that will quantitatively relate the amount of haze emanating from a transparency in terms of its measureable effect on operator visual performance. Such a technique would involve (1) obtaining measurements of the actual amount of haze in a transparency, (2) determining what effect that haze had on a task being performed by an operator, and (3) using the obtained data, in conjunction with pilot complaints, to arrive at a decision as to when such a transparency is needed to be replaced.

As a first step towards the development of such a technique, an experiment was designed and conducted to determine what relationship, if any, existed between the amount of haze emanating from a transparency and the amount of the observer's field-of-view (FOV) or visual field that was "lost", i.e., rendered unusable due to the amount of haze present and the effect of this haze on the performance of a target detection task.

METHODOLOGY

Design

Three independent variables were investigated in this study -- percent of haze emanating from a transparency (5 levels), angular direction of movement of the target (8 levels), and tilt of the haze panels to the observer's line-of-sight (3 levels). The combination of these three variables (5x8x3) resulted in a total of 120 treatment conditions. Dependent variables used to evaluate subject performance were (a) the distance the target had traveled before being detected and (b) number of misses.

Subjects

Ten subjects, 8 males and 2 females, ranging in age from 20 - 29 years participated in this study. They were all selected from a paid, volunteer subject pool. Each subject was tested to determine ocular dominance and to ensure that he/she had 20/20 vision in his/her dominant eye. Eight of the subjects were right-eye dominant and two were left-eye dominant. All subjects were tested under all treatment conditions, treatment conditions being spread over 15 sessions or days.

Apparatus

The apparatus used in the conduct of this experiment consisted of two major pieces of equiment -- four calibrated haze panels and a background screen. Additional periphery equipment needed in support of the major pieces were also available and are described later.

Haze Panels: Four haze panels, made from 2 x 2 foot acrylic panels, that generated a variable percentage of haze (as measured by the Gardner Hazemeter) were used. The first panel indicated a haze reading that ranged from 2%-3.5%; the second indicated a reading that ranged from 5%-10%; the third from 15%-26%; and the fourth from 25%-48%. A zero haze or 0% condition,

in which no panel was used, served as a control or baseline condition. A 7/8-inch diameter annulus was positioned in the center of each panel and served to protect the subject from having the bright light source shine directly into his/her eye. The subject wore an eyepatch over the nondominant eye. The annulus was also present in the 0% haze condition. Figure 1 shows one of the haze panels (25%-48%) used.

Background Screen: The background screen against which the target was viewed was a 6 x 6 foot square terrain board made from a laminated aluminum honeycomb plate that was mounted approximately 29 inches above the floor. The board was covered with a white sheet of paper in order to provide a homogeneous background. Thirty concentric circles, one inch apart, were drawn on the sheet of paper. These circles were used to determine the distance that the target had traveled before being detected. Mounted to the back of the terrain board was a 110.5 x 7 inch rotating arm with 40 x 7 inch wingtips. Mounted at the center of each wingtip was a pulley, one of which was motorized. These pulleys extended beyond the front surface of the board and were used to move the target which was attached to a clear monofilament string wrapped around them. A protractor was mounted at the center of rotation of the arm and was used to accurately determine the angular direction in which the target moved. A 300 watt, ELH projector lamp served as the light source for illuminating the haze panels. The lamp was mounted at the center of the front surface of the board but slightly forward of the surface so as not to interfere with the movement of the target. A baffle was attached to the back of the lamp in order to prevent back illumination. Figure 2 shows the background screen with the rotating arm in the horizontal position. Also shown are the 30 concentric circles, the centrally positioned light source, and the string to which the target was attached.

Accessory Equipment: Additional equipment employed included (1) two ColorTran photo flood lights which were positioned above and behind the subject to eliminate shadows on the background screen; (2) two control boxes,

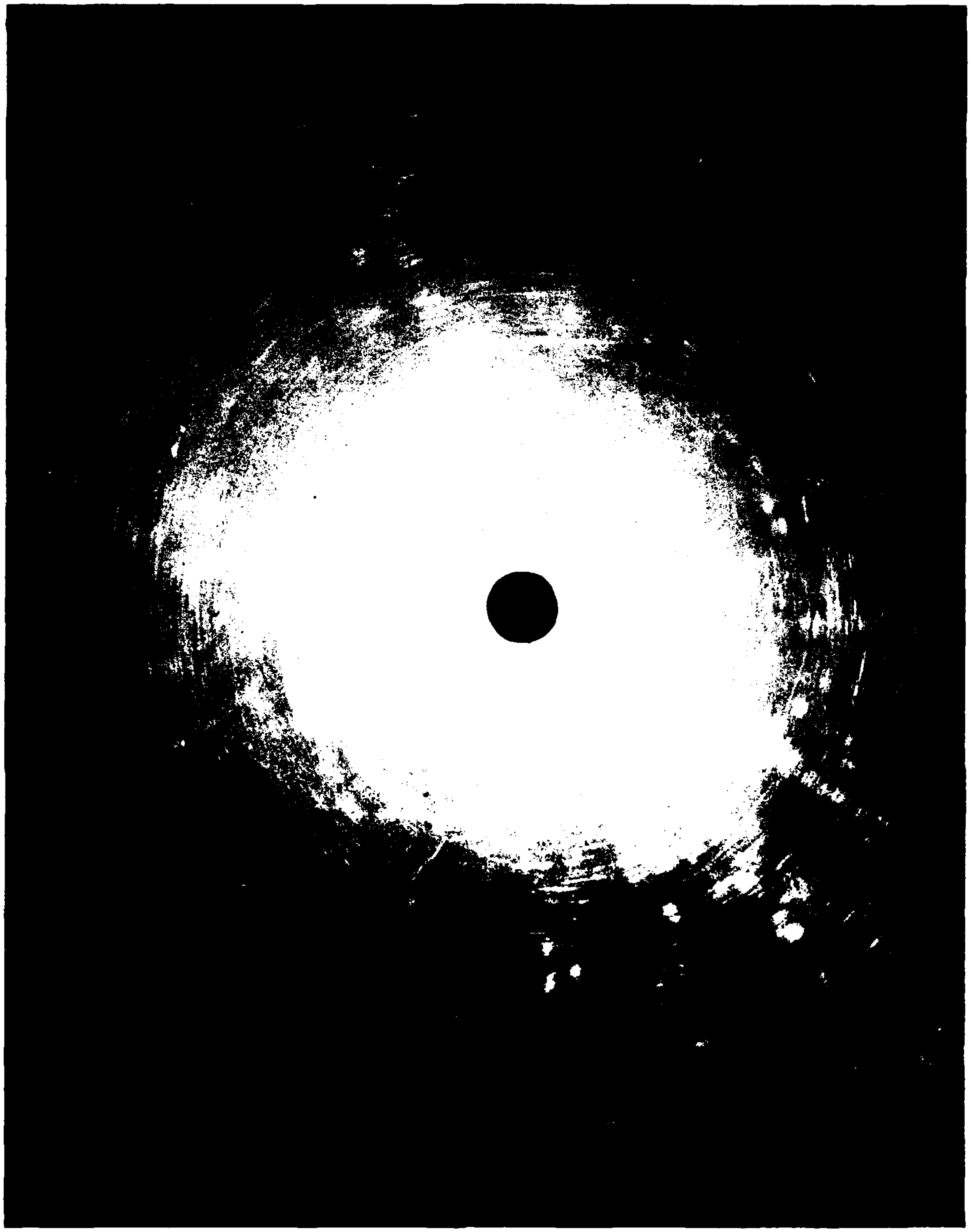

Figure 1. One of the haze panels used. Note 7/8 inch diameter annulus located in the center of the panel

Figure 2. Background screen used with bright light source located in the center.

one to control the intensity of the light source and one to control the speed of the target; (3) two tripods, one to hold the fixture to which the haze panels were mounted and one to hold the subject's chinrest; and (4) two switches, one used by the experimenter to position the target and one used by the subject to stop the target.

Task

The task used was a detection task. Subjects were required to indicate when they could see a slowly moving, 1 minute of arc, 80% contrast target that traveled in 8 (0, 45, 90, 135, 180, 225, 270 or 315 degrees) different angular directions from the center of the background screen to the periphery. The subjects performed the above task while looking through the haze panels that were mounted at 90, 63 or 45 degrees to their line of sight (LOS) and which, when illuminated by the light source, resulted in haze readings of 2%-3.5%, 5%-10%, 15%-26%, and 25%-48%. As a matter of convenience, these haze conditions will hereinafter be referred to (by their average) as the 2.75%, 7.5%, 20.5% and 36.5% haze conditions. A baseline condition, in which no test panel was interposed between the subject, the task and the light source, was also administered. The exposure of each subject to each haze condition was counterbalanced while the direction of movement of the target was randomized.

Procedure

During the conduct of this experiment, the following procedure was adhered to: Each subject was required to serve for a total of 15 sessions over a period of 15 days. On the first day, when the subject arrived at the test site he/she was instructed as to the purpose of the experiment, the task to be performed, and the manner in which he/she was to respond. Any and all questions were answered at this time. The subject was then seated at a distance of 13 feet from the background screen and tested under the 0% haze or control condition. The subject's dominant eye was aligned behind the black annulus, located 3 feet in front of him/her and in the center of his/her FOV. The annulus prevented the subject from staring directly into the light source. The subject's other eye was covered with an eyepatch. A chinrest was used to keep the subject from moving his/her head. Figure 3 shows the experimental

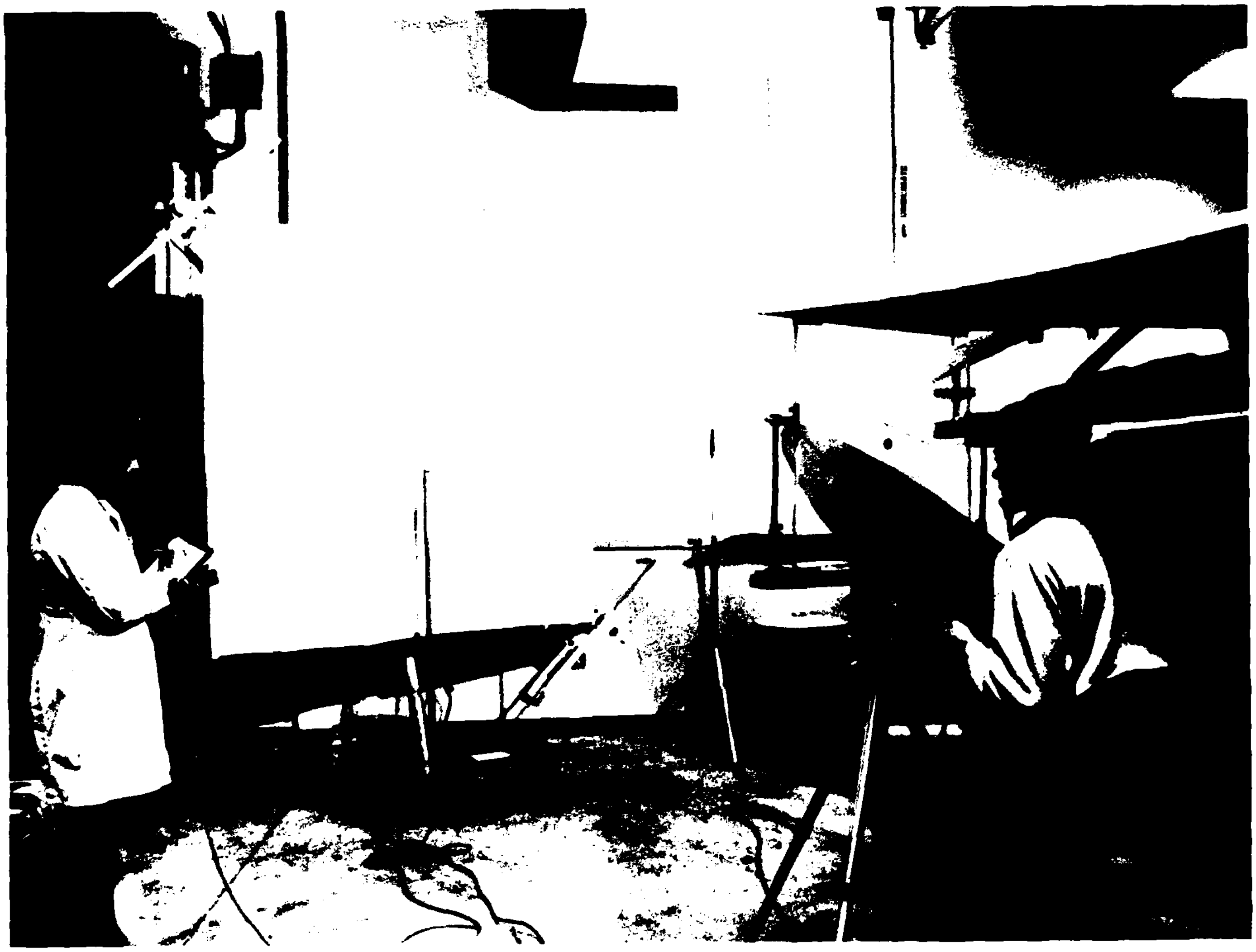

Figure 3. The experimental setup used showing relationships between the haze panel, background screen and subject.

arrangement used. All subjects were tested under the control condition first. In subsequent sessions, the subject was tested under the 2.75%, 7.5%, 20.5% or 36.5% haze condition with the panel mounted at 90^{o}, 63^{o}, or 45^{o} to his/her LOS. The order of exposure to these conditions was counterbalanced to combat order or practice effects. The subjects performed 8 times under each condition.

During a given trial, the following sequence of events took place: After the subject was seated at his/her station, the experimenter positioned the target behind the light source at the center of the background screen. The rotating arm was positioned at one of the eight angular directions used. The experimenter then triggered a switch which started the target moving from the center of the screen to the periphery. As soon as the subject detected the target, he/she activated the response switch which stopped the target. The experimenter then measured and recorded the distance the target had traveled and also elicited a verbal response from the subject as to the direction it had been moving. This latter response was used to determine if the subject had indeed detected the target. This entire sequence was then repeated until the required number of trials was completed.

RESULTS

The measures used to evaluate subject performance were (a) the distance the target had traveled before being seen and (b) the number of times that it was not detected (misses). The first measure provides the data required for deriving "contour maps" of the visual area of the background FOV that is lost due to the amount of haze present while the second measure provides an indication of the effect of this haze on visual performance.

The data obtained are shown in Tables 1 and 2. Table 1 shows the mean distances that the target traveled before being detected. Table 2 shows the number of misses that occurred under each treatment condition. Immediately apparent from an examination of these two tables is the fact that as the

percent of haze increased, the distance that the target traveled and the number of misses also increased. It is also apparent that the angle at which the panel was mounted did not effect the distance traveled measure but seem to have some influence on the number of misses that occurred.

Using the data from Table 1, contour maps of the areas "lost" as a function of the haze present are shown in Figures 4, 5, and 6 for each of the angles at which the panels were mounted. Examination of these figures shows, quite obviously, the increase in the area that is lost (occluded) as the percent of haze increases. Irregularities in the contours seem to indicate that the angular direction in which the target moved had some influence on the distance that the target traveled before being detected.

Although the data from Table 1 and Figures 4, 5, and 6 are helpful in showing the trends that occurred, no figure of merit can be attributed to these trends. The following technique was used, therefore, to further examine the data. The scores for each haze condition were collapsed across the variable of angular direction to obtain an average for that condition. These averages are shown as the last line of Table 1. Since the target always moved from the center of the background screen to the periphery, the assumption was made that these averages represented radii of various-sized, circular FOVs. These averages were doubled and then used to determine the FOV that each haze condition occluded. The FOVs obtained and the percent of the background FOV that it occluded are shown in Table 3. The percentages were obtained by dividing the obtained FOVs by the background FOV (26.45^{o}) and multiplying the resultant quotient by 100.

Figure 7 shows these percentages plotted as a function of the amount of haze present. Two things are immediately apparent from this figure. First we see a rapid increase in the percent of the background FOV that is occluded as the percent of haze increases. Secondly, the angle at which the panel was mounted to the observer's line-of-sight did not influence the amount (percent) of the area that was lost. It is of interest to point out that the

Table 1

MEAN DISTANCE TRAVELED (INCHES)

	Percent Haze												
	0.0	2.75			7.5			20.5			36.5		
Angular Direction		90°	63°	45°	90°	63°	45°	90°	63°	45°	90°	63°	45°
0	3.20	8.06	8.98	6.78	12.91	12.81	12.88	19.00	21.31	20.04	24.09	22.75	23.25
45	3.23	5.58	9.75	7.25	7.73	9.60	8.88	17.58	18.08	18.61	22.12	27.25	25.25
90	3.18	6.00	7.00	5.63	10.67	15.13	11.25	21.00	20.68	19.94	24.19	25.08	24.14
135	2.83	4.33	5.90	6.23	8.10	10.78	8.40	19.48	23.73	21.34	23.78	20.25	23.80
180	3.35	7.25	10.19	7.83	11.80	12.92	9.83	23.25	10.25	25.13	21.03	26.75	11.75
225	2.91	6.75	5.75	5.38	8.75	8.83	6.90	20.05	21.60	17.64	23.31	22.40	20.38
270	2.95	8.90	6.83	5.50	13.53	10.00	9.28	22.78	15.47	16.89	19.88	16.31	16.39
315	3.11	6.05	7.15	6.95	8.50	9.53	8.85	16.25	18.48	17.28	23.25	20.56	20.19
	3.10	6.62	7.69	6.44	10.25	11.20	9.53	19.92	18.70	19.61	22.70	22.67	20.64

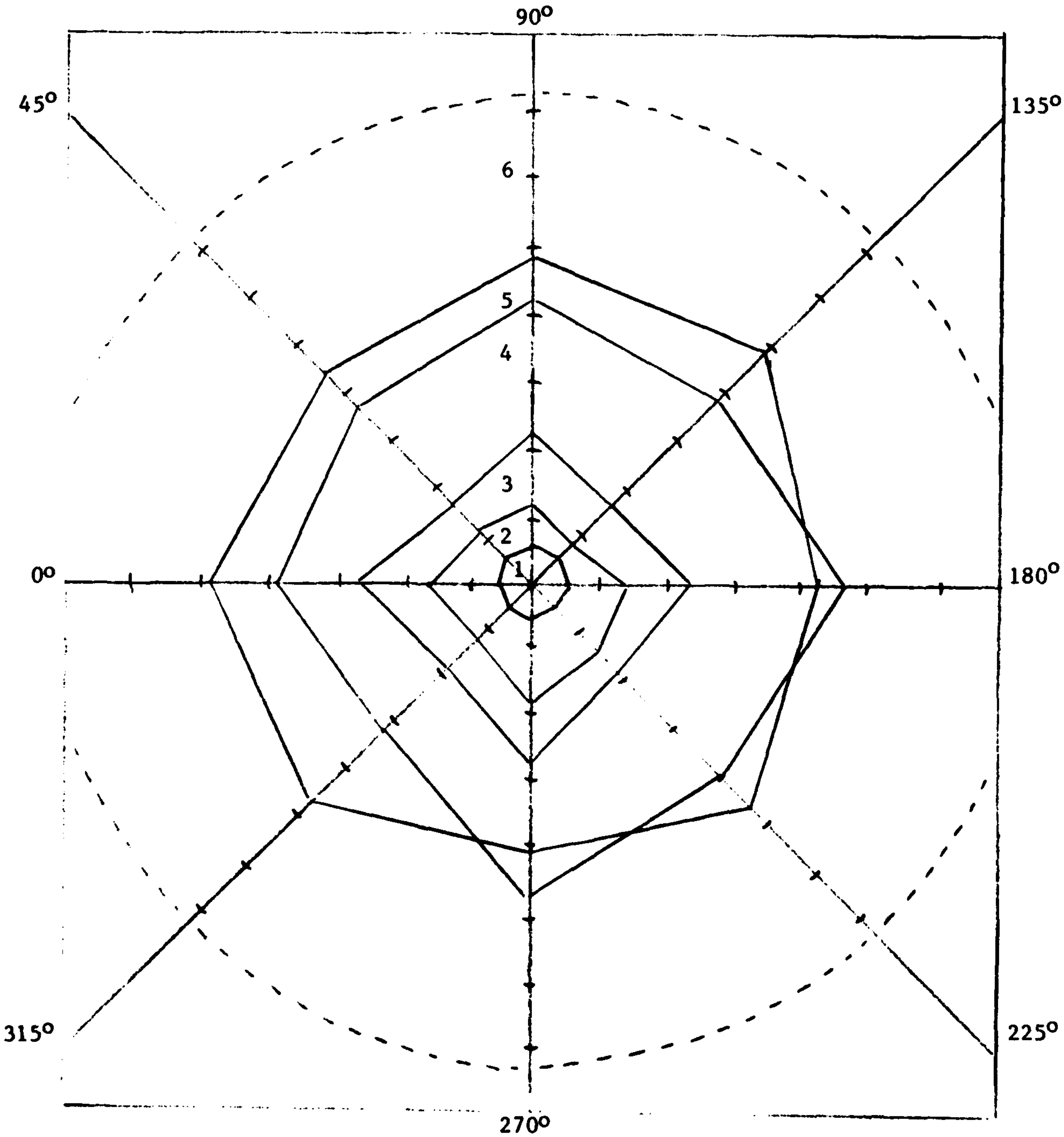

Figure 4. Regions of background FOV that is occluded as function of percent of haze for 90° mounted panel. The nos. 1, 2, 3, 4, 5 and 6 represent the 0%, 2.75%, 7.5%, 20.5%, 36.5% haze conditions and the background FOV respectively.

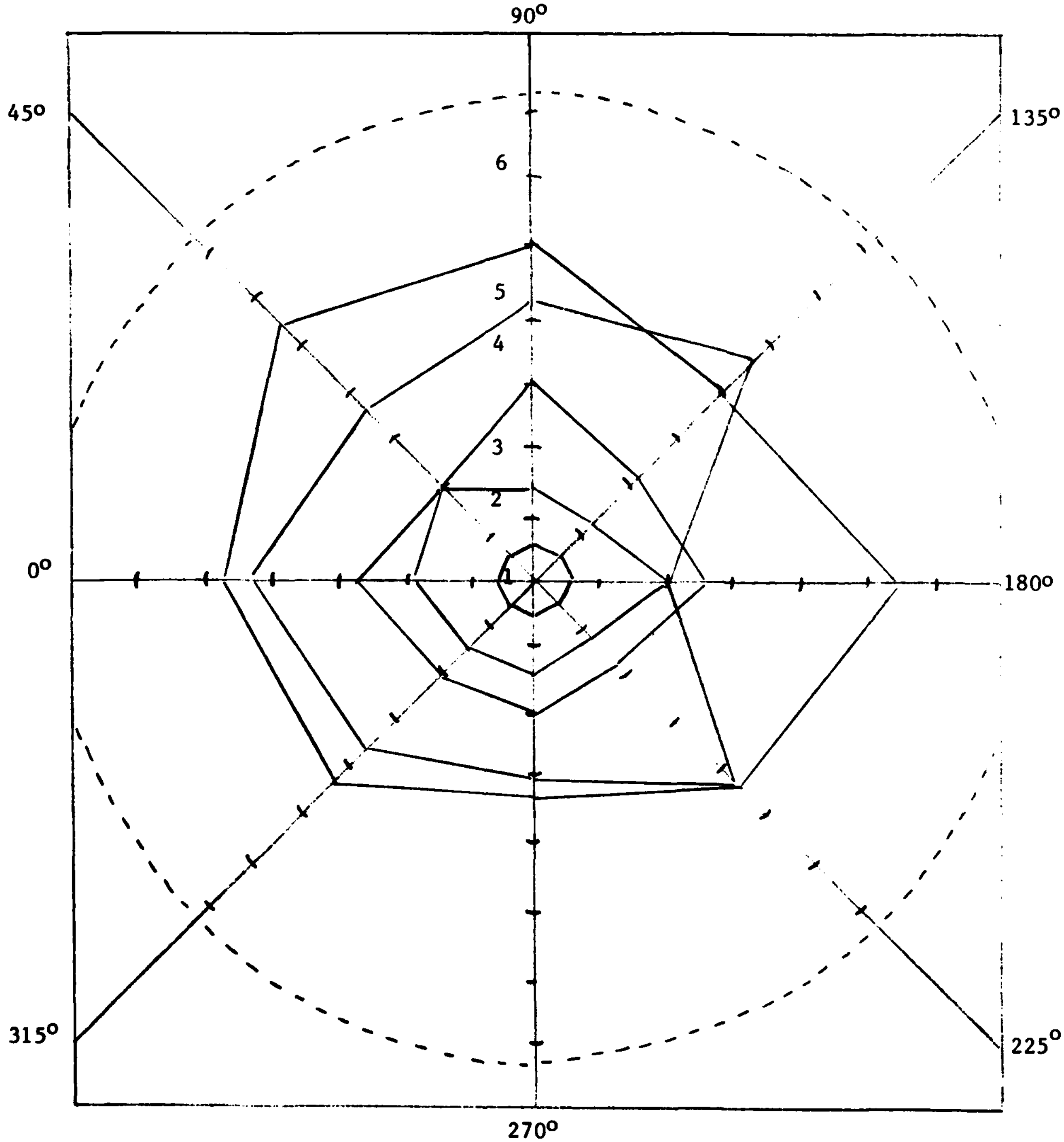

Figure 5. Regions of background FOV that is occluded as function of percent of haze for 63° mounted panel. (See Figure 4 for explanation of nos. 1, 2, 3, 4, 5 and 6).

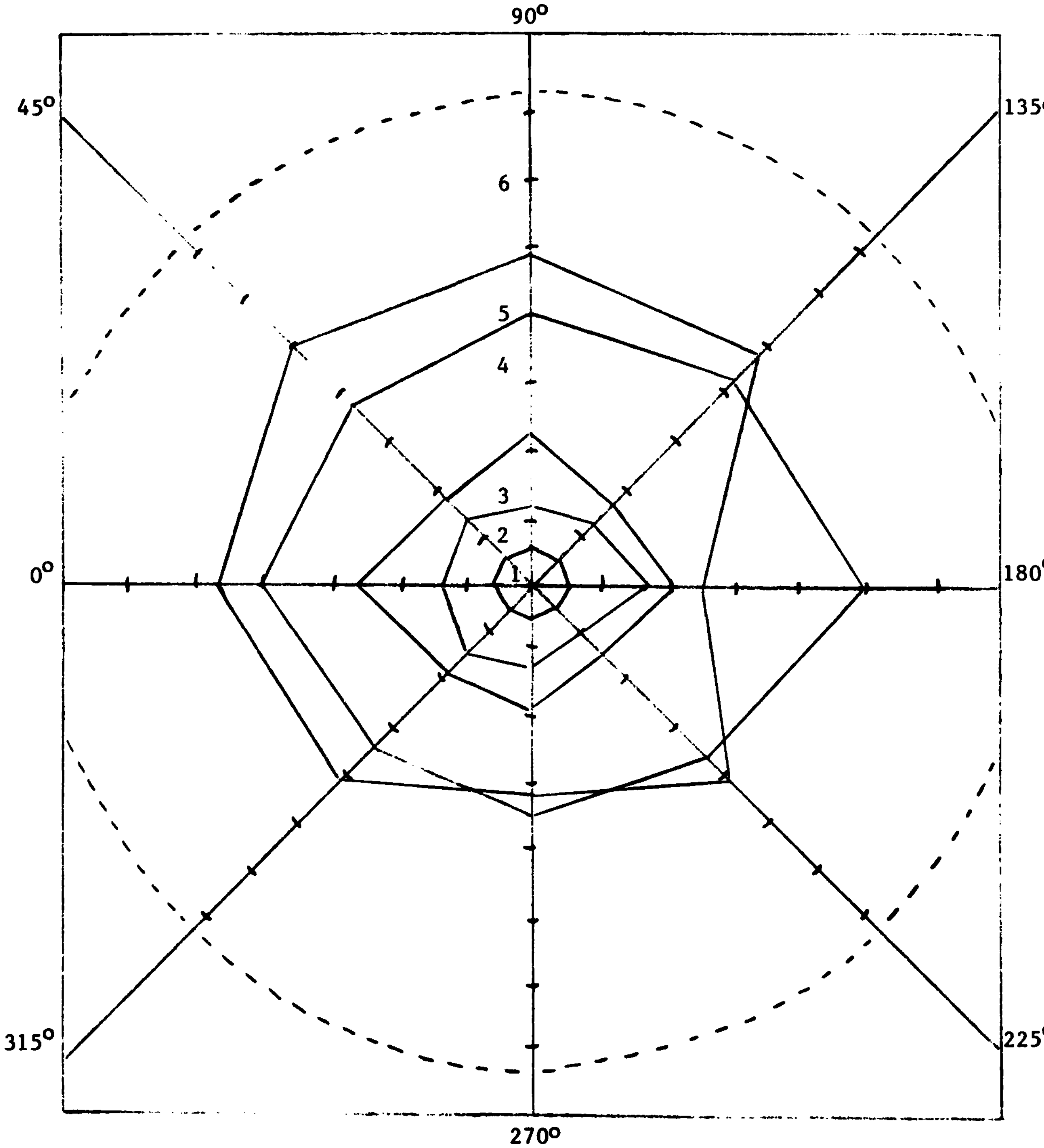

Figure 6. Regions of background FOV that is occluded as function of percent of haze for 45° mounted panel. (See Figure 4 for explanation of nos. 1, 2, 3, 4, 5 and 6).

Table 2

NUMBER OF MISSES

	Percent Haze												
	0.0		2.75			7.5			20.5			36.5	
Angular Direction		90°	63°	45°	90°	63°	45°	90°	63°	45°	90°	63°	45°
0	0	1	0	2	2	2	0	1	2	3	2	6	3
45	0	0	0	1	0	0	0	0	0	1	4	8	8
90	0	0	0	0	1	0	0	0	3	1	6	4	3
135	0	0	0	0	0	0	0	0	0	2	2	8	5
180	0	0	1	0	0	4	1	4	9	8	1	9	9
225	0	0	0	0	1	1	0	0	0	1	6	3	6
270	0	0	0	0	0	0	0	2	1	1	2	2	1
315	0	0	0	0	0	0	0	0	0	0	2	1	1
	0	1	1	3	4	7	1	7	15	17	25	41	36

Table 3

PERCENT OF FOV OCCLUDED BY HAZE

	Percent Haze												
	0.0		2.75			7.5			20.5			36.5	
		90°	63°	45°	90°	63°	45°	90°	63°	45°	90°	63°	45°
FOV(°)	2.28	4.86	5.62	4.73	7.53	8.23	7.00	14.63	13.74	14.41	16.68	16.65	15.16
FOV Occluded(%)	9	18	21	18	28	31	26	55	52	54	63	63	57

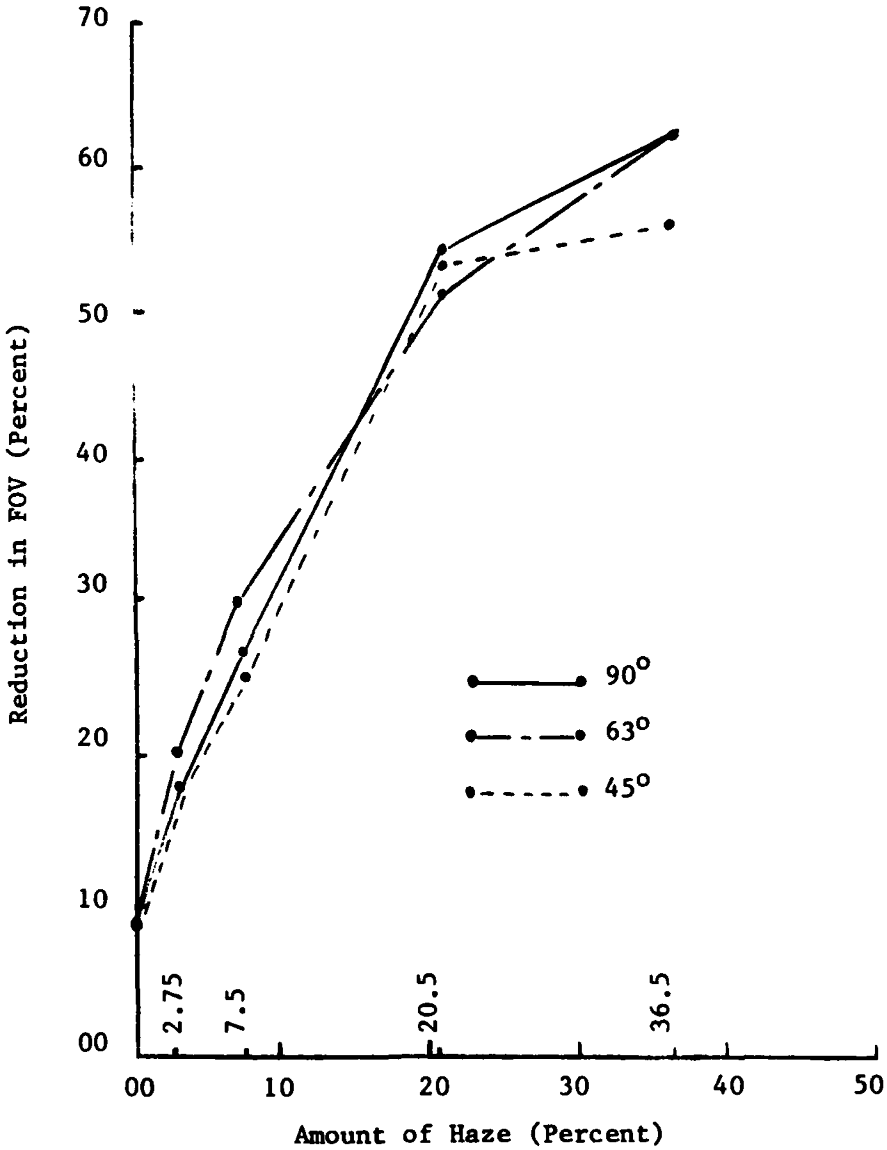

Figure 7. Reduction in FOV as a function of the amount of haze present for three panel angles.

(percent) of the area that was lost. It is of interest to point out that the percent of background FOV that is occluded increased from 9% (no haze) to 19% (2.75% haze) to 28% (7.5% haze) to 54% (20.5% haze) to 61% (36.5% haze). The loss in FOV for the no haze condition is attributed to the presence of the bright light source (causing halation within the eye) and the 7/8-inch diameter annulus used to protect the subject.

To determine the effect of haze on the observer's visual performance, the data in Table 2 were collapsed across the variable of angular direction to obtain the total number of misses that occurred for each haze condition. These are shown as the last line in Table 2. The total number of misses for each treatment condition was then divided by 80 (the number of trials per condition) and the resultant quotient multiplied by 100 to obtain the percentage of time that the target was not detected (missed). This percentage was then subtracted from 100% to obtain the percentage of time that the target was detected. These latter percentages were then plotted as a function of percent of haze and are depicted in Figure 8.

Immediately obvious from an examination of Figure 8 is the fact that as the percent of haze present increased, detection performance decreased. Additionally, this decrease seems to be influenced by the angle at which the panel was mounted to the observer's line-of-sight. The decrease was greatest when the panel was mounted at 63° (100% to 49%). For the 45° mounting angle, the decrease was from 100% to 55% while for the 90° mounting angle the decrease was from 100% to 69%. This finding would seem to indicate that the angle at which the panel was mounted and the amount of haze present interacted in some manner to influence target detection performance.

Comparing the data from Figures 7 and 8, it can be seen that when 2.75% haze was present, 19% of the FOV was occluded but detection performance still was very high, 98% of the targets being detected, when they emerged from the occluded area. When the amount of haze present was increased to 7.5%, 28% of the FOV was occluded but again detection of the target as it emerged out of the

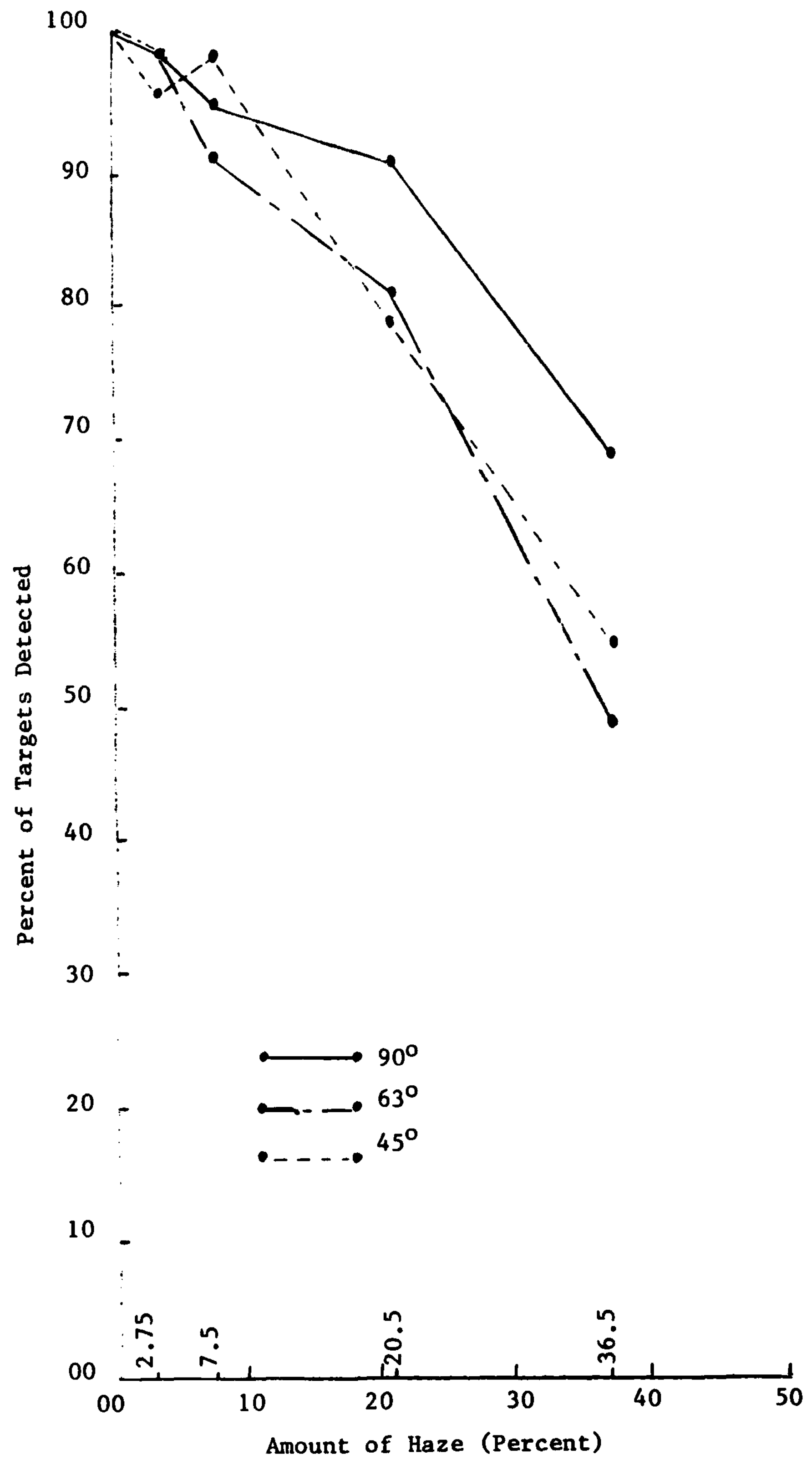

Figure 8. The percent of targets detected as a function of the amount of haze present for three panel angles.

occluded area remained high, 95% of the targets being detected. However, when the amount of haze present was increased further (20.5% and 36.5%), the percent of the FOV that was occluded became excessive (54% and 61%) and detection of the target outside of the area occluded fell off to 84% and 58% respectively.

DISCUSSION

It will be recalled that this experiment represents a first step towards the development of an objective criterion to be used in determining when aircraft transparencies should be replaced. The intent of this particular experiment was to determine what type of relationship, if any, exists between the amount of haze emanating from a transparency (as measured by the Gardner Hazemeter) and the percent of an operator's visual field that is "lost". Also of interest was the effect that the haze had on an operator's ability to perform a target detection task.

The data obtained (Figure 7) indicates that over the first four haze conditions employed (0%, 2%-3.5%, 5%-10% and 15%-26%) there is a steep rise in the percentage of the background FOV that is occluded or lost, this loss increasing from 9% to 19% to 28% to 54%. However, the increase between the fourth and fifth (15%-26% and 25%-48%) haze conditions is not as rapid, increasing from 54% to 61%.

Using the above curve, it now becomes a relatively simple task to determine how much of an operator's visual field is lost due to the amount of haze present and thus arrive at a decision as to whether a given transparency should be replaced. For example, any transparency yielding a haze reading of 15%-26% would be replaced immediately since this amount (percent) of haze results in a 54% loss in the operator's background FOV, a totally unacceptable condition. When a 5%-10% haze reading is obtained, well over a fourth (28%) of the observer's background FOV is lost. Whether this information is sufficient to justify replacing such a transparency would, of course, be dependent upon other factors.

One such factor is the effect that this haze had on an operator's visual performance. Figure 8 shows that as the percent of haze present increased, detection performance decreased. Comparing this data with that of Figure 7, we note that when 2%-3.5% haze was present, 19% of the background FOV was occluded but detection performance still was very high, 98% of the targets being detected when they emerged from behind the occluded area. When the amount of haze present was increased to 5%-10%, 28% of the FOV was occluded but again detection of the target remained fairly high, 95% of the targets being detected after they emerged from behind the occluded area. However, when the amount of haze present was increased further (15%-26% and 25%-48%), the percent of the FOV that was occluded became excessive (54% and 61%) and detection of the target as it emerged from behind the occluded area fell off to 84% and 58% respectively.

Using the data, from Figures 7 and 8, in this manner provides us with an objective "yardstick" for determining when a transparency should be replaced. For example, when 28% of the background FOV is lost there is also a 5% drop in target detection efficiency. A decision to replace or not replace a transparency can now be made based on one or both of these performance measures. In this particular case, a 28% loss in FOV might be acceptable but a drop of 5% in target detection might not be, hence a haze reading of 5%-10% in a transparency would justify the removal of that particular transparency.

Also, it is worthwhile to point-out that the results obtained gives no indication that the Gardner Hazemeter readings used in this study are directly related to or can be appropriately used to predict haze effects on visual performance.

Finally, since the subjects were able to detect the target at a fairly high detection rate after it emerged from behind the occluded area even after 28% of the background FOV was lost, it is suggested that perhaps another such study be performed to determine not only the FOV loss but also the length of time that the target is lost from view.

SUMMARY

A study was conducted to determine what type of relationship, if any, exists between the amount of haze emanating from a transparency and the percent of an operator's visual field that is "lost". The effect of this haze on an operator's ability to perform a target detection task was also determined. The results of this study indicated that as the amount of haze present increased, the percent of an operator's background FOV that is occluded increased and the percent of targets detected decreased. It is suggested that these two relationships can be used as a convenient and objective yardstick for determining when a transparency should or should not be replaced.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-760-501/196

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